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Agricultural and Forest Resource Surveys from Space

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Introduction

The efficient and effective management of the natural and cultural resources of any country requires accurate and up-to-date information concerning these resources. People involved in the management of agricultural and forest resources at the local level, as well as in various government agencies, often have particularly urgent needs for timely, reliable information concerning the extent, condition, and potential yields of these resources.

Although aerial photography has been in use for many years and for a multitude of purposes, it has only been in the past decade or so that agriculturists and foresters have been seriously researching the potentials of color infrared photography, multispectral optical-mechanical scanners, radar, and other remote sensing instruments and techniques.[3] In some cases these instrument systems have been put into operational use, and in many more situations researchers are thoroughly investigating the capabilities and limitations of the instrument systems and our ability to meaningfully interpret the data obtained from them (4, 5, 7, 10, 11). This next decade will certainly find spacecraft data being effectively utilized for many of the current and untold additional forestry and agricultural applications.

Information Needs in Agriculture and Forestry

In many situations involving surveys of agricultural and forest resources, specific types of information need to be

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[3]Remote Sensing can be defined as "the science involved with the gathering of data about the earth's surface or near-surface environment, through the use of a variety of sensor systems that are usually borne by aircraft or spacecraft, and the processing of these data into information that is useful for the understanding and/or managing of man's environment." (3)

obtained very rapidly and for large geographic areas. Satellites can be utilized to collect data over vast areas in a very short period of time, but it soon becomes apparent that for certain applications some type of automatic data processing (ADP) technique is required, in order to reduce the data collected into the required information in a timely manner. This is particularly true for agricultural situations where crop conditions can change very rapidly.

ADP techniques were applied to digitized multispectral scanner data for the first time in 1966 at LARS, Purdue, and the feasibility of these techniques has since been established for several discipline areas. Research to date has indicated that two requirements must be met in order for ADP techniques, utilizing data such as collected by ERTS-1, to be effective in identifying and mapping a particular resource situation. These requirements are that: (1) the cover type or situation of interest must be spectrally separable from other cover types in that geographic area, and (2) the spectrally separable classes that can be defined must have informational value.

There is little purpose, for example, in automatically defining and mapping thirty spectral classes of rangeland if no one can attach any meaning of informational value (economic importance) to those thirty spectral classes. Perhaps more meaningful data could be provided to the rangeland manager if only three or four classes were defined and mapped, rather than thirty! It becomes necessary, therefore, to examine the information needs of the various user groups, and attempt to define the type of information which users require that can be spectrally differentiated.

In reviewing the information needs of various user groups, the primary requirements cited most frequently involve the need for more accurate, timely, and economical information on (a) the <u>extent</u> and <u>location</u> of the resource base (both maps and tables), and (b) the <u>condition</u> of the resource (i.e. density, vigor, and health of agricultural and forest resources, degree of turbidity and pollution of water resources, etc.). When one attempts to determine the steps necessary to obtain these types of information through the use of remote sensor data, it becomes apparent that many levels of sophistication are involved. (For example, the identification of a disease condition of a particular crop species is an extremely difficult problem).

Perhaps this concept can be best illustrated by Figure 1, which emphasizes some of the information needs concerning our agricultural and forest resources. First is the requirement for identifying and mapping basic cover types, as defined at the top. This appears quite feasible, using various remote sensing

instrument systems and analysis techniques. Although there is informational value in mapping the situations defined at each level of this "Analysis Sequence", from the simplest (at the top of the chart) to the most complex (at the bottom), and there is certainly a great desire to achieve even the highly sophisticated level of mapping defined at the bottom of the chart (e.g. Southern Corn Leaf Blight), the question is raised as to whether or not all the levels and situations defined can be spectrally separated. I believe that some situations will not be able to be accurately mapped using remote sensing techniques, largely because of their natural variability, but I am also firmly convinced that many rather complex resource situations can be accurately identified and mapped.

It is also apparent that spectral data alone cannot achieve many of these information requirements, but must be used in conjunction with temporal and spatial data inputs, utilizing the advantages of various sensor systems. The ERTS-1 satellite is particularly important because it provides the first opportunity to obtain temporal data over large geographic areas, including many portions of the earth's surface not previously imaged from satellite altitudes.

The 1971 Corn Blight Watch

The potentials for achieving even the most complex level of information requirements indicated in Figure 1, were clearly demonstrated by a large scale research project conducted last year in the United States. This experiment involved the monitoring of Southern Corn Leaf Blight, a virus disease that caused major damage to the U.S. corn crop during 1970. The study utilized small scale (1:120,000) color infrared photography, and also multispectral scanner data coupled with automatic data processing techniques.[4] A seven state area in the corn belt of the U.S.

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[4]The entire experiment was termed the "1971 Corn Blight Watch" and involved the combined efforts of people from NASA, six different departments of the U.S. Department of Agriculture, the states involved, as well as the University of Michigan (who obtained the scanner data and analyzed 15 of the segments) and Purdue University (where LARS personnel were responsible for coordinating the photo-interpretation effort, for analyzing the other 15 segments of scanner data, and the data handling activities, in addition to overall coordination of the entire experiment.)

To indicate the magnitude of this experiment, it was estimated that 38,000 miles of flightlines were flown by NASA, and over 2,600 man-days were spent by field crews in obtaining the surface observation data. I believe this latter figure also indicates that remote sensing should not be considered as a technique that involves data collected only from aircraft and spacecraft altitudes.

was overflown by NASA every two weeks (weather permitting) using a specialized sampling scheme designed by the Statistical Reporting Service of the U.S. Department of Agriculture. The resultant photography was interpreted to determine the location of corn fields infected by the blight, and also the severity of the blight damage. Multispectral scanner data were also collected and analyzed every two weeks for 30 flightlines in an intensive study area in western Indiana. Detailed field observation data formed the basis for interpretation of the scanner and photographic imagery, and also for evaluation of the results. One indication of the agricultural requirement for timeliness over large areas is that data from over 1,000,000 acres in the seven state region were flown, analyzed, and reported upon every two weeks during the three month period of the experiment.

The results of this study showed the potential to identify and map corn and other crop species, to delineate acreage infected by moderate to severe levels of Southern Corn Leaf Blight, and to track the spread of this disease throughout the corn belt. The results also indicated the necessity for good sampling models as fundamental elements of remote sensing information systems. (5)

ERTS-1 Analysis Results (Oklahoma and Indiana)

Some of the first analysis results of data from the ERTS-1 satellite provide another example of the potential for using computer-analyzed remote sensor data to map agricultural and forest cover types, and to detect and map differences in spectral response due, in part, to stress conditions in vegetation. On July 25, 1972, during the first pass by ERTS-1 over the central United States, the first MSS data were collected over the Texas-Oklahoma border region. The area near the Ouachita Mountains in Oklahoma has a number of interesting geologic features, including very distinct sedimentary structures which were discernible on the ERTS imagery. This area also contains a large amount of forest cover, as well as many water resource, agricultural, and rangeland features of interest.

These data were classified by computer into spectral classes, utilizing all four wavelength bands of ERTS data. The results of this classification are shown in Figure 2, in which the individual resolution elements of the MSS data have been automatically classified and displayed as individual symbols, colors, or grey levels (depending on the mode of output). Both clustering and maximum likelihood algorithms were utilized in this classification procedure.

Five different groups of forest cover could be defined by this analysis sequence, including forested areas in different topographic positions and forested areas having a low infrared response due to stress conditions (caused by a combination of

topographic position and soil moisture conditions). Several forested areas had been aerially sprayed with 2,4,5-T, (a chemical commonly used to kill deciduous trees for purposes of rangeland improvement). These areas were distinctly defined in the ERTS data because of their low infrared reflectance. In another area, however, the spray had been applied in 1971 but had not killed the trees, and this year, when observed from a light aircraft, the area (though affected) could not be visually distinguished from the surrounding forest cover. However, this area could be accurately delineated in the infrared channels of the ERTS data (See Figure 3). Also noted was an area on top of the plateau where straight lines and rectangular corner features indicated human activity. In this case the native forest cover had been cut and wind-rowed, allowing native grasses to dominate the scene.

The distinct banding effect related to the geologic structure of the Ouachita Mountains was also very evident in the classification results. Surface observation and aerial photos of this area indicated that the spectral differences causing this banding were due to a number of different features--in some cases, limestone outcroppings caused a very distinct spectral response, and in other cases the banding effects were caused by a combination of topographic and vegetative effects.

Differences in water quality of several reservoirs were cited by local resource personnel as the reason for the distinct spectral differences found in the ERTS data, even though these differences were not particularly obvious to the eye from a light aircraft. Another example of the potential use of ERTS imagery was indicated by the accurate location and mapping of a reservoir which was not shown on even the most recent maps of the area.

Rivers and areas including the interstate highway, powerlines, a recently cut hay field, rangeland, and agricultural and range areas where a great amount of soil is exposed were also delineated and mapped. (6) These preliminary results indicate a great deal of potential for the use of ERTS data in detecting and mapping land use changes and many aspects of the agricultural and forest resource situation.

In another analysis sequence, ERTS data were collected over an area in southern Indiana on August 8th. Within 24 hours after a digitized tape of these data was received by Purdue, a reasonably accurate classification of cover types had been obtained, showing agricultural and forest cover types. After the accuracy of the classification had been established, an acreage tabulation could be rapidly computed. These rather preliminary results indicate excellent potential for rapid cover type mapping over large geographic areas using satellite data.

Operational Applications of Remote Sensing to Agriculture and Forestry

Not only do experimental results indicate the potentials for various remote sensing techniques but operational use of several sensor systems (other than standard black and white and color photography) has proven their value. For example, the U.S. Forest Service is using a thermal infrared scanner system on an operational basis for mapping the perimeter of large forest fires and providing valuable information to the fire boss in a near real-time manner. It has been estimated that this system has saved thousands of dollars each year in fire fighting costs as well as in preventing larger timber and watershed losses. (2) A two-channel thermal infrared scanner and an inexpensive, thermal "fire-spotter" show great promise for forest fire detection work. The U.S. Forest Service has also been using color infrared photography on an operational basis for several years in conducting Southern Pine Beetle surveys. (1)

Certainly one of the largest operational programs to date that involves some of the newer remote sensor systems is Project RADAM in Brazil. (9) Using an X-band radar system, as well as a battery of supplemental sensors, Project RADAM has collected data over the entire Amazon basin--an area where cloud cover had thwarted any previous attempts to collect photographic data. This radar imagery has very good geometric characteristics, making it useful in obtaining 1:250,000 scale mosaics of the area. These are then interpreted for several types of information, including agricultural and forest resources. Geologic, hydrologic, vegetation, and soils maps are also being produced from RADAM data. The results of this project, made possible because of advances in remote sensing technology, will have a tremendous impact on the future of Brazil.

Summary and Conclusions

The need to continue development and refinement of the techniques required for better management of our natural resources is obvious. One of the major factors which will influence many decisions on the use of vegetation, soil, water and cultural resources is the amount and detail of information available about their area, location, and condition. Remote sensing has already proved to be a very useful tool in this respect and research has indicated a tremendous potential for both automated and manual analysis techniques to be used in soils mapping, crop yield predictions, acreage determinations, damage assessment, and other benefits in addition to those discussed above.

Without question, the results from the ERTS-1 and subsequent experimental and operational satellites will establish the value of data obtained from space and provide many types of information necessary for understanding and effectively managing our earth's resources.

Acknowledgement

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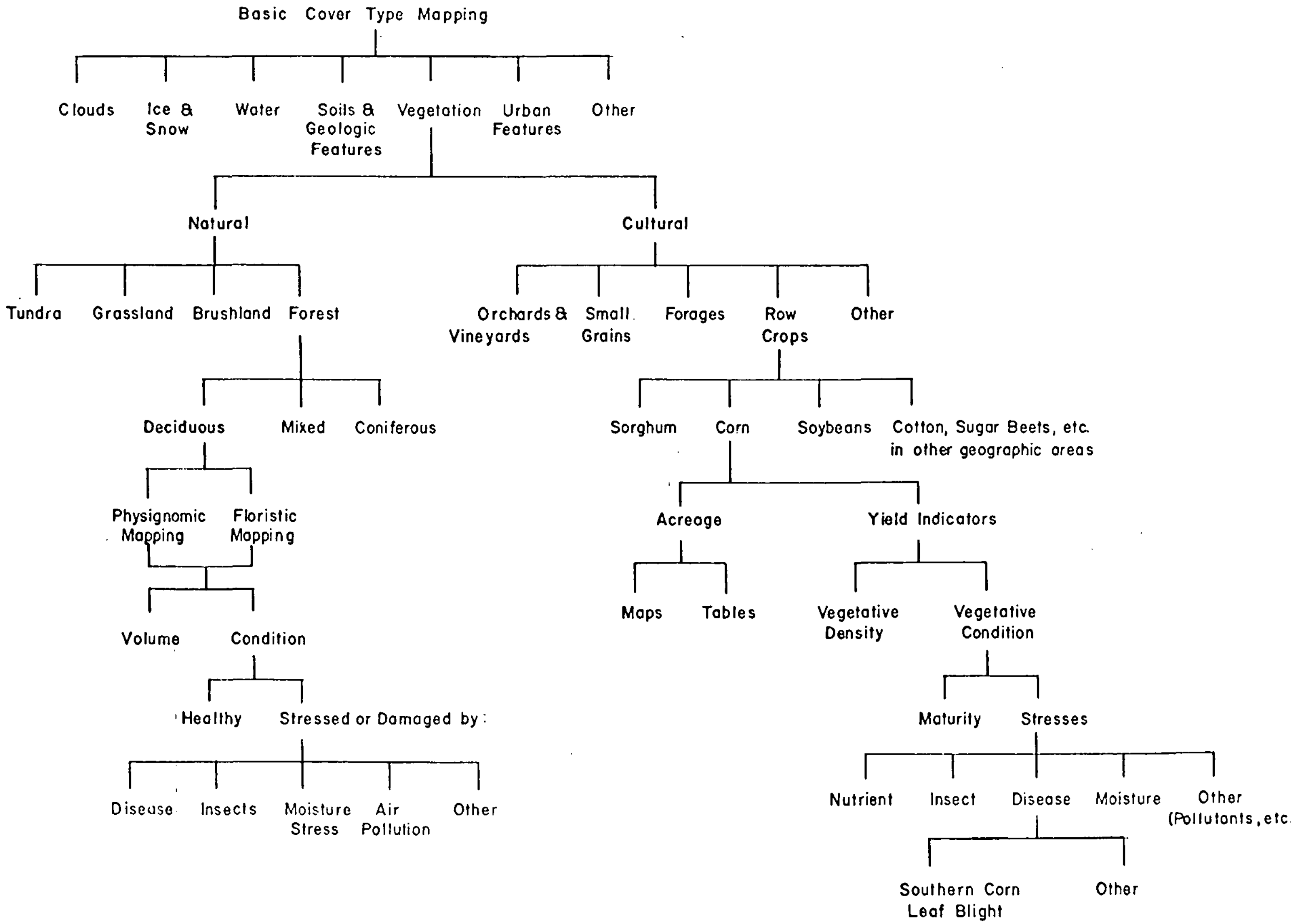


Figure 1 -- An earth resources data analysis sequence for selected cover types, based upon spectral characteristics and user requirements.

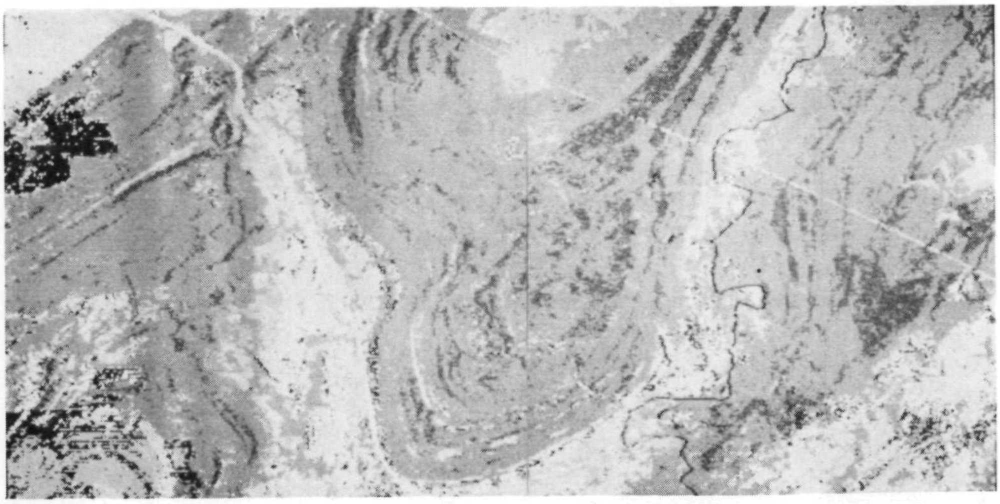
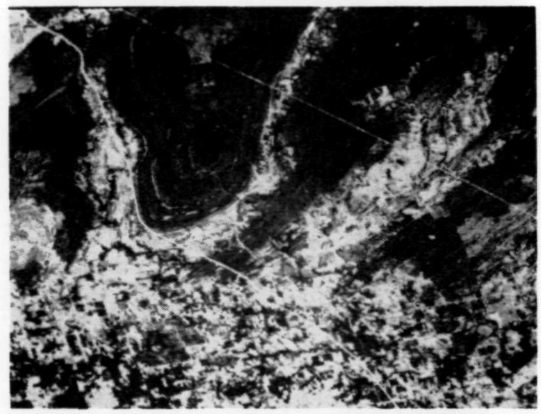
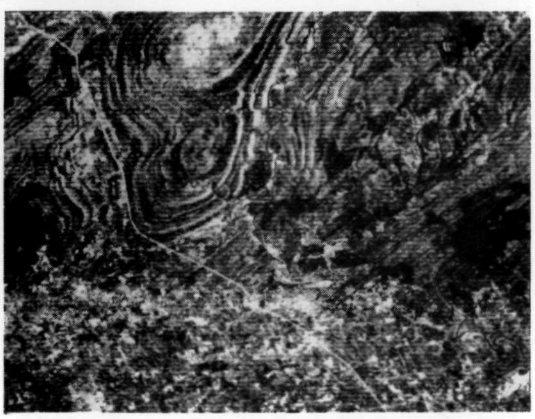


Figure 2 -- Classification results for the Ouachita Mountain portion of ERTS Frame No. 1002-16312.

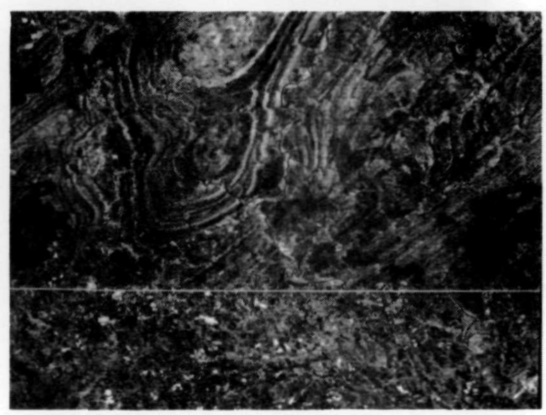
Channel 4
0.5-0.6μm



Channel 5
0.6-0.7μm



Channel 6
0.7-0.8μm



Channel 7
0.8-1.1μm

Figure 3 -- Displays of the four individual wavelength bands of ERTS-1 MSS data collected over the Ouachita Mountain area, Oklahoma, on July 25, 1972.